PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:)
Supratik Guha et al.)
Serial No.: 10/699,399)
Group Art Unit: 2859)
Filed: October 30, 2003)
Examiner: Mirellys Jagan)
For: TRANSPARENT COOLING DUCT)
________________________________)

APPEAL BRIEF

MS-APPEAL BRIEF-PATENTS
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

This Appeal Brief is filed in response to a Final Office Action dated December 4, 2006, followed by a Notice of Appeal with Pre-Appeal Conference Request Brief filed March 5, 2007, and received a Notice of Panel Decisions from Pre-Appeal Brief Review dated March 28, 2007. Reconsideration of the Application, withdrawal of the rejections, and allowance of the claims are respectfully requested.

CERTIFICATE OF TRANSMISSION

I hereby certify that this correspondence is being electronically sent to: Mail Stop Appeal Brief-Patent, Commissioner for Patents, on the date shown below.

ON: May 5, 2007 BY: Jon A. Gibbons

SIGNATURE: /Jon Gibbons/

I. REAL PARTY IN INTEREST

The real party in interest is International Business Machines (IBM) of Armonk, NY.

II. RELATED APPEALS AND INTERFERENCES

There are no related appeals or interferences.

III. STATUS OF CLAIMS

Claims 1, 2, 8, 13, 14, 20, 24-28, 31 and 32 have been canceled.

Claims 11, 12 and 23 have been withdrawn.

Claims 3-7, 9, 10, 15-19, 21, 22, 29 and 30 have been rejected.

The Appellant is appealing the rejection of independent claims 7 and 19.

IV. STATUS OF AMENDMENTS

The Examiner issued a final rejection of claims 3-7, 9-10, 15-19, 21-22, and 29-30 in the Final Office Action of December 4, 2006. In response, Appellants filed a Notice of Appeal with Pre-Appeal Conference Request Brief on March 5, 2007. Appellants subsequently received a Notice of Panel Decisions from Pre-Appeal Brief Review on March 28, 2007.

V. SUMMARY OF THE CLAIMED SUBJECT MATTER

It should be noted that individual paragraphs in the text of the original application as filed were sequentially numbered beginning with 0001. Support for the claims under appeal is adequately provided in the specification and the drawings.

There are two (2) independent claims under appeal in this case, namely, claim 7: "A system for measuring thermal distributions of an electronic device during operation" and claim 19: "A method for detecting thermal characteristics of an electronic device during operation".

Independent claim 7 claims the following subject matter.

Claim 7. A system for measuring thermal distributions of an electronic device during operation, comprising:

A) a duct adapted to be coupled with an electronic device, wherein the electronic device forms one side of the duct; Summary at pages 3-4 (para 0008); FIG. 8, and the Specification at pages 16-17 (paras 0053-0057).

B) a coolant flowing through the duct so as to cool the electronic device; Summary at pages 3-4 (para 0008), FIG. 8, and the Specification at pages 16-17 (paras 0053-0057).

C) and, a photon detector located adjacent to the duct for detecting photons emitted from the electronic device, wherein the duct and the coolant are at least partially transparent to photons with wavelengths above 3.6 microns and the duct is made of at least one of polished silicon, quartz, sapphire, glass, and diamond. Summary at page 4 (para 0009), FIG 8, and the Specification at pages 16-17 (paras 0053-0057).

Independent claim 19 claims the following subject matter.

Claim 19. A method for detecting thermal characteristics of an electronic device during operation, comprising:

A) detecting, by a photon-detector, photons from an electronic device during operation of the electronic device, the photons indicative of thermal characteristics of the electronic device, the photon detector located adjacent to a duct that is adjacent to the electronic device, wherein the electronic device forms one side of the duct and a coolant flows through the duct so as to cool the electronic device and the duct and the coolant are at least partially transparent to photons with wavelengths above 3.6 microns and the duct is made of at least one of polished silicon, quartz, sapphire, glass and diamond. Summary at page 4 (para 0009), FIG 8, and the Specification at pages 16-17 (paras 0053-0057).

VI. GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL

Whether the combination of *Davidson* (US 6,140,141) and *Paniccia* (US 6,251,706), as set forth in both the June 26, 2006 non-final Office Action and the December 4, 2007 Final Office Action, is proper.

VII. ARGUMENT

Appellant's independent system claim 7 recites, *inter alia*:

7. A system for measuring thermal distributions of an electronic device during operation, comprising:

a duct adapted to be coupled with an electronic device, wherein the electronic device forms one side of the duct;

a coolant flowing through the duct so as to cool the electronic device; and,

a photon detector located adjacent to the duct for detecting photons emitted from the electronic device, wherein the duct and the coolant are at least partially transparent to photons with wavelengths **above 3.6 microns** and the duct is made of **at least one of polished silicon, quartz, sapphire, glass, and diamond**. [emphasis added]

Appellant's independent method claim 19 recites, *inter alia*:

19. A method for detecting thermal characteristics of an electronic device during operation, comprising:

detecting, by a photon-detector, photons from an electronic device during operation of the electronic device, the photons indicative of thermal characteristics of the electronic device, the photon detector located adjacent to a duct that is adjacent to the electronic device, wherein the electronic device forms one side of the duct and a coolant flows through the duct so as to cool the electronic device and the duct and the coolant are at least partially transparent to photons with wavelengths **above 3.6 microns** and the duct is

made of **at least one of polished silicon, quartz, sapphire, glass and diamond**. [emphasis added]

Appellant respectfully asserts that Appellant's invention is not obvious under 35 U.S.C. §103(a) and therefore is patentable over *Davidson* in view of *Paniccia* for the following reasons.

Briefly, Appellant's invention is a device for measuring thermal distributions on a chip. The device includes a duct located above, and coupled to, an electronic device. The duct has an at least partially transparent upper wall that is made of polished silicon, quartz, sapphire, glass, or diamond and uses an upper surface of the electronic device as its bottom wall. Within the duct is a transparent fluid that flows over the top surface of the electronic device to cool the device. (See, paras. 0053 and 0056, and FIG. 8). A photon detector is located above the chip and measures infrared radiation emitted by the chip to calculate a thermal distribution of heat on the chip. For proper measurement of a thermal distribution, the photon detector must see through the upper surface of the duct and fluid to the back surface of the chip throughout the entire infrared frequency range. The infrared frequency range includes wavelengths between 2.6 microns to 20 microns. The materials (the duct and the coolant) were selected because these were at least partially transparent to photons with wavelengths above 3.6 microns. Since few materials are transparent at these wavelengths, Appellant claimed the use of polished silicon, quartz, sapphire, glass, and diamond, because these materials are transparent to frequencies having wavelengths above 3.6 microns.

Davidson discloses a system comprising a duct adapted to be coupled with an electronic device, wherein the duct forms one side of the duct; a coolant flowing through the duct so as to cool the electronic device; and a photon detector (radiation detector 145) located adjacent to the duct for detecting photons emitted from the electronic device; wherein the duct and coolant are at least partially transparent to photons with wavelengths between about 0.1 micron to 20 microns (1 micron); the coolant is either water or a perflourocarbon; the duct comprises a window of quartz or glass; and the

device includes a protecting outer layer (is packaged) (see Figs 2 and 3; col 2, line 30 – col 3, line 2; and col 3, lines 39-49). On page 3 of the Office Action dated Dec. 4, 2006, the Examiner states “Davidson does not disclose the duct being made of at least one of polished silicon, quartz, sapphire, glass, and diamond; ...”.

Paniccia discloses a system for testing an electronic device during operation by detecting photons (IR radiation) from the device through an IR-transparent window made of diamond, silicon or sapphire that is couple to the device. The material of the window is thermally conductive, and is chosen depending on the heat removal requirements of the device (see col 5, lines 51-65). A photon detector comprising an IR camera is located adjacent the device to detect the photons emitted by the device for use by its processor in generating a thermal map of the device, the camera capturing thermal information from the device during operation of the device under conditions for which the device is designed. *Paniccia* discloses that it is known in the art to determine the voltage levels of the device as well as thermal information of the device by detecting photon emissions from the device when testing the device at its operation capacity, and that the IR camera can determine the voltage levels of the device as well as thermal information. The thermal information allowing proper thermal regulation of the device to prevent thermal degradation (see Fig 7D, col 1, line 66 – col 2, line 9; col 2, lines 26-35 and 43-55; and col 7, lines 13-37).

The United States Supreme Court recently issued an opinion regarding the issue of obviousness under 35 USC §103(a) when the claim recites a combination of elements of the prior art. See *KSR Int'l Co. v. Teleflex, Inc.* No. 04-1350 (U.S. Apr. 30, 2007)[1].

In *KSR Int'l*, the Court reaffirmed the *Graham*[2] factors in determining obviousness under 35 U.S.C §103(a). The four factual inquiries under *Graham* are:

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1 See, http://www.supremecourtus.gov/opinions/06pdf/04-1350.pdf

2 Graham v. John Deere, 383 U.S. 1, 17-18, 148 USPQ 459, 467 (1966)

1) determining the scope and contents of the prior art;
2) ascertaining the differences between the prior art and the claims in issue;
3) resolving the level of ordinary skill in the pertinent art; and
4) evaluating evidence of secondary consideration.

The Supreme Court did not totally reject the use of “teaching, suggestion, or motivation” as a factor in the obviousness analysis. Rather, the Court recognized that a showing of “teaching, suggestion, or motivation” to combine the prior art to meet the claimed subject matter could provide a helpful insight in determining whether the claimed subject matter is obvious under 35 USC §103(a). The Court rejected a rigid application of the “teaching, suggestion, or motivation” test which required a showing of some teaching, suggestion, or motivation in the prior art that would lead one of ordinary skill in the art to combine the prior art elements in the manner claimed in the application or patent before holding the claimed subject matter to be obvious. The Court noted that the analysis supporting a rejection under 35 USC §103(a) should be made explicit and that it was important to identify a reason that would have prompted a person of ordinary skill in the relevant field to combine the prior art elements in the manner claimed. The Court stated:

> Often, it will be necessary ... to look to interrelated teachings of multiple patents; the effects of demands known to the design community or present in the marketplace; and the background knowledge possessed by a person having ordinary skill in the art, all in order to determine whether there was **an apparent reason** to combine the known elements in the fashion claimed by the patent at issue. To facilitate review, this analysis **should be made explicit**. (emphasis added)

KSR Int'l, slip op. at 14 (emphasis added).

Thus, in formulating an obviousness rejection under 35 USC §103(a) based upon a combination of prior art elements, it remains necessary to identify the reason why a person of ordinary skill in the art would have combined the prior art elements in the manner claimed.

The Examiner's reason, as stated on page 4 of the December 4, 2007 Final Office Action, is given as: "*By replacing the window with a window as taught by Paniccia, in order to provide a window having a desired thermal conductivity to remove heat depending on the heat removal requirements of a particular application, and since the particular type of material used to make the window is only considered to be the use of a "preferred" or "optimum" material out of a plurality of well know materials that a person having ordinary skill in the art at the time the invention was made would have been able to provide based on intended use of applicant's apparatus, ire., suitability for the intended use of applicant's apparatus, which in this case is to provide a window that is partially transparent to photons with wavelengths above 3.6 microns, as taught by Davidson and Panicking.*"

The Examiner asserts that a selection of a material on the basis of suitability for intended use of an apparatus would be entirely obvious. *In re Leshin*, 125 USPQ 416 (CCPA 1960).

Appellant respectfully asserts that there is no teaching, suggestion, or motivation to combine these references.

Davidson is not directed towards a device for measuring thermal distributions of chips but for sensing voltages of signals on a die. (*Davidson*, col. 3, lines 41-42) In *Davidson*, the voltages are not measured by sensing infrared radiation but by sensing a polarization of light reflected back from the device (Col. 1, lines 25-29) or by measuring the intensity of near-infrared radiation (Col. 2, lines 58-60) emitted from the circuit. Near-infrared radiation has a defined range of wavelengths between 0.75 and 2.5 microns. *Davidson* discloses two materials that are used for the window: fused quartz, and BK-7 glass. (*Davidson*, col. 3, lines 1-2).

Paniccia discloses a window material that is transparent to IR wavelengths, *Paniccia* does not teach nor suggest the window being part of a cooling system that

uses coolant flowing through a duct so as to cool an electronic device.

Davidson does not operate in the IR frequency range. (*Davidson*, col. 2, line 59). The two materials specifically called out by *Davidson*, namely fused quartz and BK-7 glass, are sufficient for the near-infrared radiation range that *Davidson* operates in. (*Davidson*, col. 4, lines 1 and 2). Thus, one would have no motivation to take the IR transparent window material from *Paniccia*, a reference that does not even pertain to liquid cooling, and exchange it for the upper window of a cooling duct in *Davidson*. In addition, *Davidson* is not concerned with generating a thermal distribution. In *Davidson*, the voltages are not measured by sensing infrared radiation, but by sensing a polarization of light reflected back from the device (Col. 1, lines 25-29) or by measuring the intensity of near-infrared radiation (Col. 2, lines 58-60) emitted from the circuit.

Davidson does not disclose a duct that is at least partially transparent to photons with wavelengths above 3.6 microns and made of at least one of polished silicon, quartz, sapphire, glass, and diamond.

In addition, *Paniccia* doesn't have, teach, or suggest a duct with coolant flowing through it, as recited in the independent claims of the instant application. Therefore, one of ordinary skill would not be motivated to combine *Paniccia* with *Davidson.*

Further, when there is no suggestion or teaching in the prior art, the suggestion or motivation can not come from the Applicant's specification. The Federal Circuit has warned against using the Applicant's disclosure as a blueprint to reconstruct the claimed invention out of isolated teachings of the prior art. See MPEP §2143 and <u>Grain Processing Corp. v. American Maize-Products</u>, 840 F.2d 902, 907, 5 USPQ2d 1788 1792 (Fed. Cir. 1988) and <u>In re Fitch</u>, 972 F.2d 160, 12 USPQ2d 1780, 1783-84 (Fed. Cir. 1992).

The prior art reference *Davidson* taken alone and/or in view of *Paniccia* does not suggest, teach or mention "a duct adapted to be coupled with an electronic device,

wherein the electronic device forms one side of the duct; a coolant flowing through the duct so as to cool the electronic device; and a photon detector located adjacent to the duct for detecting photons emitted from the electronic device, wherein the duct and the coolant are at least partially transparent to photons with wavelengths above 3.6 microns and the duct is made of at least one of polished silicon, quartz, sapphire, glass, and diamond," as recited in independent claim 7 of the instant application. The prior art reference *Davidson* taken alone and/or in view of *Paniccia* also does not suggest, teach or mention "detecting, by a photon-detector, photons from an electronic device during operation of the electronic device, the photons indicative of thermal characteristics of the electronic device, the photon detector located adjacent to a duct that is adjacent to the electronic device, wherein the electronic device forms one side of the duct and a coolant flows through the duct so as to cool the electronic device and the duct and the coolant are at least partially transparent to photons with wavelengths above 3.6 microns and the duct is made of at least one of polished silicon, quartz, sapphire, glass and diamond," as recited

Paniccia taken alone and/or in view of *Davidson* does not suggest, teach or mention a duct partially transparent to photons with wavelengths above 3.6 microns and made of at least one of polished silicon, quartz, sapphire, glass and diamond.

Even if there was a motivation to combine the references, it is well established that references that teach away (produce an inoperable result) cannot serve to create a prima facie case of obviousness. See, McGinley v. Franklin Sports, Inc., 262 F.3d 1339, 60 USPQ2d 1001 (Fed Cir 2001). See also, In re Gurley, 27 F.3d 551, 553, 31 USPQ2d 1131, 1132 (Fed. Cir. 1994). If references taken in combination would produce a "seemingly inoperative device," such references teach away from the combination and thus cannot serve as predicates for a prima facie case of obviousness. In re Sponnoble, 405 F.2d 578, 587, 160 USPQ 237, 244 (CCPA 1969) (references teach away from combination if combination produces seemingly inoperative device); see also In re Gordon, 733 F.2d 900, 902, 221 USPQ 1125, 1127 (Fed. Cir. 1984) (inoperable modification teaches away).

On page 2 of the June 26, 2006 Office Action, the Examiner states "fused quartz (up to 3.6 microns) or BK7 glass (0.25 to 2.9 microns)" and this is clearly the range claimed in independent claims 1 and 17 of "wavelengths above 3.6 microns". By the Examiner's own admission, fused quartz and BK-7 glass are inoperable for the thermal imaging of Appellant's invention above 3.6 microns. In other words, if one were to take the glass of *Paniccia* and replace it with the glass of *Davison*, the IR detector of *Paniccia* would no longer function because IR wavelengths cannot pass through fused quartz or BK-7 glass. **During the prosecution history of this case, Appellant amended the independent claims on appeal specifically to include the "above 3.6 microns" limitation because the Examiner indicated that Davidson was inoperable at this level. See page 2 of Office Action dated June 26, 2006.** What is the motivation to combine these two references if the result to one skilled in this art is readily inoperable?

Appellant submitted a Declaration under 37 C.F.R. §1.132 from Dr. Emanuel Tutue, a researcher at IBM who is familiar with infra-red radiation along with the corresponding general wavelength of transmission of two groups of materials: i) fused quartz and B-K glass and ii) polished silicon, quartz, sapphire, glass and diamond. The Declaration of Dr. Tutue supports Appellant's argument that fused quartz and BK-7 glass are inoperable for thermal imaging above 4 microns. Appellant also has included herewith printouts of three (3) websites providing data on wavelength transmissions through BK7 glass and fused quartz.

Since *Davidson* and *Paniccia* produce a clearly inoperable result, one would not be motivated to take the IR transparent window of *Paniccia* and place it in the liquid cooling duct of *Davidson* because the materials recited in *Davidson* for sensing polarization of light work well for their intended use, which is at lower wavelengths. Further, one would not be motivated to take the IR camera of *Paniccia* and use it to replace the polarization sensing device of *Davidson*, simply because *Davidson* would no longer be able to sense voltages through detection of light polarization. Thus, *Davidson*

would be inoperable. References that produce seemingly inoperative devices cannot serve as predicates for a *prima facie* case of obviousness.

Accordingly, Appellant respectfully asserts that it was improper to combine Davidson in view of Paniccia to reject Appellant's application under 35 U.S.C. 103(a). Accordingly, Appellant respectfully requests that the rejection be withdrawn and the Examiner's decision reversed.

VIII. CONCLUSION

For the reasons stated above, the Appellant respectfully contends that each claim is patentable. Therefore, reversal of all rejections is courteously solicited.

Respectfully submitted,

Dated: May 5, 2007 By: /Jon Gibbons/
Jon A. Gibbons, Reg. No. 37,333
Attorney for Appellant

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VIII. CLAIMS APPENDIX

Claim 1. (canceled)

Claim 2. (canceled)

Claim 3. The system of claim 7, further comprising:

a processor coupled to the photon detector for generating a thermal distribution of the electronic device based on information received from the photon detector.

Claim 4. The system of claim 7, wherein the coolant comprises any one of water and a cold gas.

Claim 5. The system of claim 7, wherein the coolant comprises at least one of any alkanes and perfluoroalkanes.

Claim 6. The system of claim 7, wherein the coolant is a non-polar liquid comprising any one of perflouro-octane, perfluro-hexane, octane, hexane and carbon tetrachloride.

Claim 7. A system for measuring thermal distributions of an electronic device during operation, comprising:

a duct adapted to be coupled with an electronic device, wherein the electronic device forms one side of the duct;

a coolant flowing through the duct so as to cool the electronic device; and

a photon detector located adjacent to the duct for detecting photons emitted from the electronic device, wherein the duct and the coolant are at least partially transparent to photons with wavelengths above 3.6 microns and the duct is made of at least one of polished silicon, quartz, sapphire, glass, and diamond.

Claim 8. (canceled)

Claim 9. The system of claim 7, wherein the photon detector captures thermal information from the electronic device during operation of the electronic device, wherein the electronic device is operating under conditions for which the electronic device is designed.

Claim 10. The system of claim 7, wherein the photon detector is an infrared camera.

Claim 11. The system of claim 1, wherein the photon detector detects photons reflected from the electronic device.

Claim 12. (withdrawn).

Claim 13. (canceled)

Claim 14. (canceled)

Claim 15. The method of claim 19, further comprising:

generating a thermal distribution of the electronic device based on information received from the photon detector.

Claim 16. The method of claim 19, wherein the coolant comprises any one of water and a cold gas.

Claim 17. The method of claim 19, wherein the coolant comprises at least one of any alkanes and perfluoroalkanes.

Claim 18. The method of claim 19, wherein the coolant is a non-polar liquid comprising any one of perflouro-octane, perfluoro-hexane, octane, hexane, and carbon tetrachloride.

Claim 19. A method for detecting thermal characteristics of an electronic device during

operation, the method comprising:

detecting, by a photon-detector, photons from an electronic device during operation of the electronic device, the photons indicative of thermal characteristics of the electronic device, the photon detector located adjacent to a duct that is adjacent to the electronic device, wherein the electronic device forms one side of the duct and a coolant flows through the duct so as to cool the electronic device and the duct and the coolant are at least partially transparent to photons with wavelengths above 3.6 microns and the duct is made of at least one of polished silicon, quartz, sapphire, glass and diamond.

Claim 20. (canceled)

Claim 21. The method of claim 19, wherein the photon detector captures thermal information from the electronic device during operation of the electronic device, wherein the electronic device is operating under conditions for which the electronic device is designed.

Claim 22. The method of claim 19, wherein the photon detector is an infrared camera.

Claim 23. (withdrawn).

Claim 24. (canceled)

Claim 25. (canceled)

Claim 26. (canceled)

Claim 27. (canceled)

Claim 28. (canceled)

Claim 29. The system of claim 7, wherein the electronic device includes a protecting outer layer.

Claim 30. The method of claim 19, wherein the electronic device includes a protecting outer layer.

Claim 31. (canceled)

Claim 32. (canceled)

IX. EVIDENCE APPENDIX

1) Declaration under 37 C.F.R. §1.132 from Dr. Emanuel Tutue

2) Printouts of:

http://www.harricksci.com/infoserver/Optical%20Materials/BK-7%20Glass.cfm

http://www.mellesgriot.com/products/optics/mp_3_1.htm

http://www.mellesgriot.com/products/optics/mp_3_2.htm.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.	:	10/699,399	Confirmation No.: 3291
Applicant	:	Supratik Guha	
Filed	:	October 30, 2003	
TC/A.U.	:	2859	
Examiner	:	Mirellys JAGAN	
Docket No.	:	YOR920030425US1	
Customer No.	:	23334	

37 C.F.R. § 1.132 DECLARATION

I, the undersigned, hereby declare the following:

1) My name is _**Emanuel Tutuc**_______

2) I am __31__ years of age.

3) I reside at _1870 Baldwin Rd, Unit 46, Yorktown Heights, NY 10598_.

4) I am a citizen of the Romania.

5) I currently work as a _Post Doctoral Researcher__ for International Business Machines (IBM) Corporation.

6) I have a Bachelor's degree in Physics from the University of Paris, and a doctorate (Ph.D.) degree in Physics from Princeton University. I am the co-inventor on two patents pending and authored 46 journal archived publications.

7) I have _8_ years of experience working as a _physicist______.

8) I am familiar with thermal imaging. I have reviewed the above-reference patent application along with Davidson patent (U.S. Patent No. 6,140,141).

9) I am familiar with the general wavelength range of transmission of two groups of materials: i) fused quartz and BK-7 glass and ii) polished silicon, quartz, sapphire, glass, and diamond. More specifically I am familiar with infrared radiation through the above two groups of materials.

9) In my opinion both the fused quartz and BK-7 glass are inoperable for thermal imaging because they are not transparent to wavelengths above 4 microns, corresponding to a temperature of 455C. For at least these reasons, it is my expert technical opinion that the Davidson patent is inoperable for thermal imaging under 455C, because of the use of fused quartz and BK-7 glass.

I, the undersigned, hereby declare that all statements made herein are of my own knowledge and are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. § 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Name: _Emanuel Tutuc_: Signature: ________________ Date: September 25, 2006

Optical Materials

BK-7 Glass

Optical Material Information*

Chemical Formula	BK-7 Glass
Refractive Index (Wavelength)	1.50
Knoop Hardness (psi)	520
Modulus of Rupture (psi)	2400
Useful Wavelength Range, Transmission (microns)	0.32-2.30
Useful Wavelength Range, ATR	0.34-1.97
Melting Point (ºC)	820
Chemical Properties	Insoluble in water.
Clean with...	Water.

*This was compiled from various sources. For more details, consult the Chemical Abstracts Service at www.cas.org.

Transmission Spectrum

Harrick Scientific Products, Inc.
141 Tompkins Ave, 2nd floor
PO Box 277
Pleasantville, NY 10570
Phone: 914-747-7202
Fax: 914-747-7209
E-mail: info@harricksci.com

Material Properties

...ost important optical and physical constants for Schott optical ...3aK1, and F2. These types are used in most Melles Griot simple ... refraction and transmission, as well as the most commonly ...nd mechanical constants, are listed. Further numerical data and a ...rious testing processes can be found in the Schott Optical Glass

The index of refraction data were obtained by using the constants listed below together with the dispersion formula. The constants were determined through the index-of-refraction measurements of a typical melt for each glass type. Note that the dispersion formula is valid only within the wavelength range listed. It can be used to interpolate refractive index at other wavelengths within this range (to a precision of 1×10^{-5} or better), but it should not be used to extrapolate to wavelengths beyond this range. Furthermore, the actual melt-to-melt tolerance on the index of refraction typically is about ±0.001.

BK7 Glass

Abbé Constant: 64.17

Density:2.51 g/cm^{-3}

Young's Modulus: 8.20×10^{9} dynes/mm^{2}

Poisson's Ratio: 0.206

Coefficient of Thermal Expansion (-30° to +70°C): 7.1×10^{-6}/°C

Coefficient of Thermal Expansion (20° to 3000°C): 8.3×10^{-6}/°C

Stress Birefringence, (Yellow Light): 10 nm/cm

Homogeneity within Melt: $\pm 1 \times 10^{-4}$

Striae Grade (MIL-G-174-A): A

Transformation Temperature: 557°C

Climate Resistance: 2

Stain Resistance: 0

Acid Resistance: 1.0

Alkali Resistance: 2.0

Phosphate Resistance: 2.3

Knoop Hardness: 610

Dispersion Constants:

$B_1 = 1.03961212$

$B_2 = 2.31792344 \times 10^{-1}$

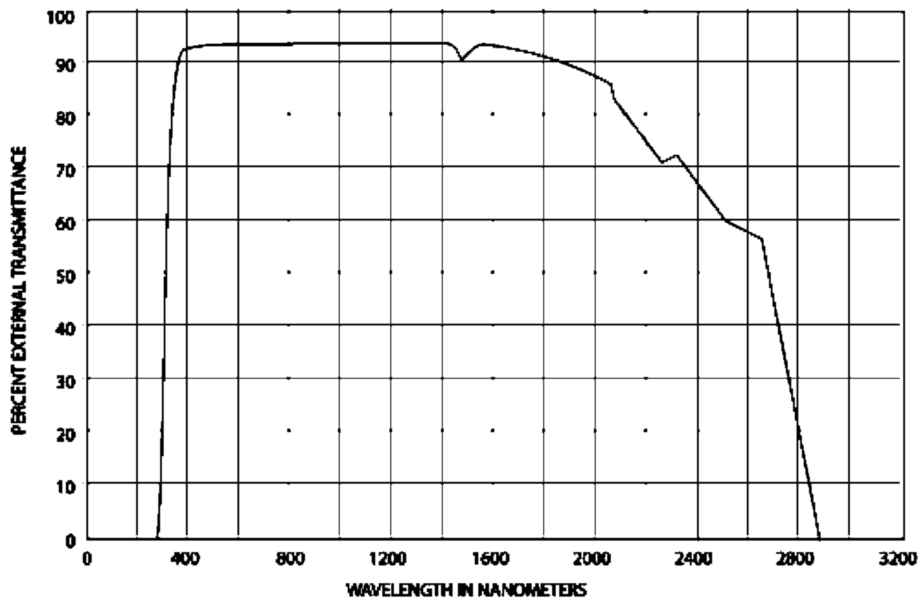
$B_3 = 1.01046945$

$B_3 = 1.01046945$

$C_1 = 6.00069867 \times 10^{-3}$

$C_2 = 2.00179144 \times 10^{-2}$

$C_3 = 1.03560653 \times 10^{2}$



External transmission for 10-mm-thick BK7 glass

Physical Constants of BK7 Glass

Wavelength (nm)	Refractive Index n	Fraunhofer Designation	Source	Spectral Region
351.1	1.53894	--	Ar laser	UV
363.8	1.53649	--	Ar laser	UV
404.7	1.53024	h	Hg arc	Violet
435.8	1.52668	g	Hg arc	Blue
441.6	1.52611	--	HeCd laser	Blue
457.9	1.52461	--	Ar laser	Blue
465.8	1.52395	--	Ar laser	Blue
472.7	1.52339	--	Ar laser	Blue
476.5	1.52309	--	Ar laser	Blue
480.0	1.52283	F'	Cd arc	Blue
486.1	1.52238	F	H_2 arc	Blue
488.0	1.52224	--	Ar laser	Blue
496.5	1.52165	--	Ar laser	Green
501.7	1.52130	--	Ar laser	Green
514.5	1.52049	--	Ar laser	Green
532.0	1.51947	--	Nd laser	Green
546.1	1.51872	e	Hg arc	Green

587.6	1.51680	d	He arc	Yellow
589.3	1.51673	D	Na arc	Yellow
632.8	1.51509	--	HeNe laser	Red
643.8	1.51472	C'	Cd arc	Red
656.3	1.51432	C	H_2 arc	Red
694.3	1.51322	--	Ruby laser	Red
786.0	1.51106	--	--	IR
821.0	1.51037	--	--	IR
830.0	1.51020	--	GaAlAs laser	IR
852.1	1.50980	s	Ce arc	IR
904.0	1.50893	--	GaAS laser	IR
1014.0	1.50731	t	Hg arc	IR
1060.0	1.50669	--	Nd laser	IR
1300.0	1.50370	--	InGaAsP laser	IR
1500.0	1.50127	--	--	IR
1550.0	1.50065	--	--	IR
1970.1	1.49495	--	Hg arc	IR
2325.4	1.48921	--	Hg arc	IR

SF11 Glass

Abbé Constant: 25.76

Density: 4.74 g/cm^{-3}

Young's Modulus: 6.60 x 10^{9} dynes/mm^{2}

Poisson's Ratio: 0.235

Coefficient of Thermal Expansion (-30° to +70°C): 6.1 x 10^{-6}/°C

Coefficient of Thermal Expansion (20° to 3000°C): 6.8 x 10^{-6}/°C

Stress Birefringence, (Yellow Light): 10 nm/cm

Melt-to-Melt Mean Index Tolerance: ±0.001

Homogeneity within Melt: ±1 x 10^{-4}

Striae Grade (MIL-G-174-A): A

Transformation Temperature: 505°C

Climate Resistance: 1

Stain Resistance: 0

Acid Resistance: 1.0

Alkali Resistance: 1.2

Phosphate Resistance: 1.0

Knoop Hardness: 450

Dispersion Constants:

B_1 = 1.73848403

B_2 = 3.11168974x10^{-1}

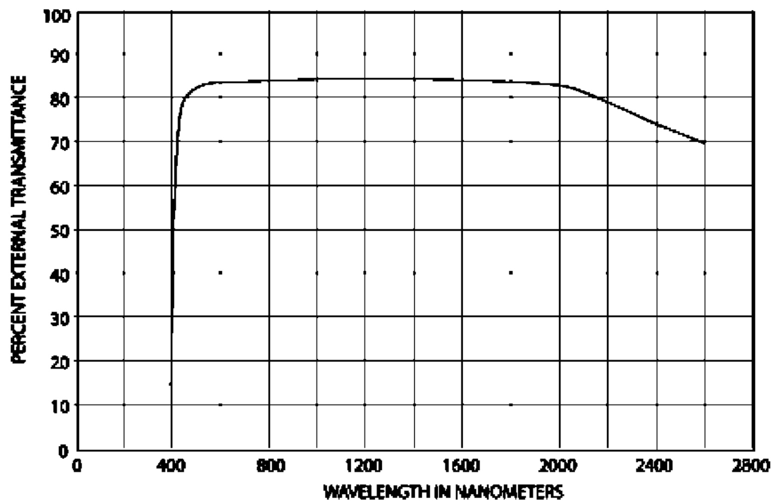
$B_2 = 3.11168974 \times 10^{-1}$

$B_3 = 1.17490871$

$C_1 = 1.36068604 \times 10^{-2}$

$C_2 = 6.15960463 \times 10^{-2}$

$C_3 = 1.21922711 \times 10^{2}$



External transmission for 10-mm-thick SF11 glass

Physical Constants of SF11 Glass

Wavelength (nm)	Refractive Index *n*	Fraunhofer Designation	Source	Spectral Region
404.7	1.84208	h	Hg arc	Violet
435.8	1.82518	g	Hg arc	Blue
441.6	1.82259	--	HeCd laser	Blue
457.9	1.81596	--	Ar laser	Blue
465.8	1.81307	--	Ar laser	Blue
472.7	1.81070	--	Ar laser	Blue
476.5	1.80946	--	Ar laser	Blue
480.0	1.80834	F'	Cd arc	Blue
486.1	1.80645	F	H_2 arc	Blue
488.0	1.80590	--	Ar laser	Blue
496.5	1.80347	--	Ar laser	Green
501.7	1.80205	--	Ar laser	Green
514.5	1.79880	--	Ar laser	Green
532.0	1.79479	--	Nd laser	Green
546.1	1.79190	e	Hg arc	Green
587.6	1.78472	d	He arc	Yellow
589.3	1.78446	D	Na arc	Yellow
632.8	1.77862	--	HeNe laser	Red
643.8	1.77734	C'	Cd arc	Red

656.3	1.77599	C	H_2 arc	Red
694.3	1.77231	--	Ruby laser	Red
786.0	1.76558	--	--	IR
821.0	1.76359	--	--	IR
830.0	1.76311	--	GaAIAs laser	IR
852.1	1.76200	s	Ce arc	IR
904.0	1.75970	--	GaAs laser	IR
1014.0	1.75579	t	Hg arc	IR
1060.0	1.75445	--	Nd laser	IR
1300.0	1.74901	--	InGaAsP laser	IR
1500.0	1.74554	--	--	IR
1550.0	1.74474	--	--	IR
1970.1	1.73843	--	Hg arc	IR
2325.4	1.73294	--	Hg arc	IR

LaSFN9 Glass

Abbé Constant: 32.17

Density: 4.44 g/cm^{-3}

Young's Modulus: 1.09 x 10^{10} dynes/mm^2

Poisson's Ratio: 0.286

Coefficient of Thermal Expansion (-30° to +70°C): 7.4 x 10^{-6}/°C

Coefficient of Thermal Expansion (20 °to 3000°C): 8.4 x 10^{-6}/°C

Stress Birefringence, (Yellow Light): 10 nm/cm

Melt-to-Melt Mean Index Tolerance: ±0.002

Homogeneity within Melt: ±1 x 10^{-4}

Striae Grade (MIL-G-174-A): A

Transformation Temperature: 703°C

Climate Resistance: 2

Stain Resistance: 0

Acid Resistance: 2.0

Alkali Resistance: 1.0

Phosphate Resistance: 1.0

Knoop Hardness: 630

Dispersion Constants:

B_1 = 1.97888194

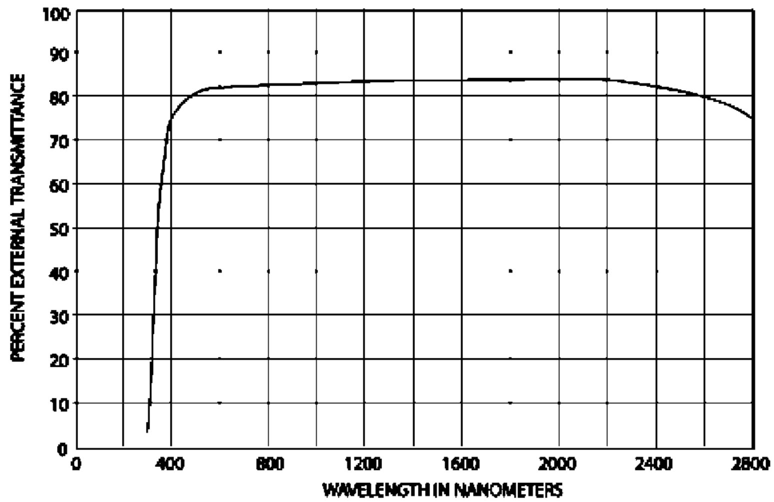
B_2 = 3.20435298x10^{-1}

B_3 = 1.92900751

C_1 = 1.18537266x10^{-2}

C_2 = 5.27381770x10^{-2}

$C_3 = 1.66256540 \times 10^2$



External transmission for 10-mm-thick LaSFN9 glass

Physical Constants of LaSFN9 Glass

Wavelength (nm)	Refractive Index *n*	Fraunhofer Designation	Source	Spectral Region
404.7	1.89844	h	Hg arc	Violet
435.8	1.88467	g	Hg arc	Blue
441.6	1.88253	--	HeCd laser	Blue
457.9	1.87700	--	Ar laser	Blue
465.8	1.87458	--	Ar laser	Blue
472.7	1.87259	--	Ar laser	Blue
476.5	1.87153	--	Ar laser	Blue
480.0	1.87059	F'	Cd arc	Blue
486.1	1.86899	F	H_2 arc	Blue
488.0	1.86852	--	Ar laser	Blue
496.5	1.86645	--	Ar laser	Green
501.7	1.86524	--	Ar laser	Green
514.5	1.86245	--	Ar laser	Green
532.0	1.85901	--	Nd laser	Green
546.1	1.85651	e	Hg arc	Green
587.6	1.85025	d	He arc	Yellow
589.3	1.85002	D	Na arc	Yellow
632.8	1.84489	--	HeNe laser	Red
643.8	1.84376	C'	Cd arc	Red
656.3	1.84256	C	H_2 arc	Red
694.3	1.83928	--	Ruby laser	Red
786.0	1.83323	--	--	IR
821.0	1.83142	--	--	IR

830.0	1.83098	--	GaAlAs laser	IR
852.1	1.82997	s	Ce arc	IR
904.0	1.82785	--	GaAS laser	IR
1014.0	1.82420	t	Hg arc	IR
1060.0	1.82293	--	Nd laser	IR
1300.0	1.81764	--	InGaAsP laser	IR
1500.0	1.81412	--	--	IR
1550.0	1.81329	--	--	IR
1970.1	1.80657	--	Hg arc	IR
2325.4	1.80055	--	Hg arc	IR

BaK1 Glass

Abbé Constant: 57.55

Density: 3.19 g/cm^{-3}

Young's Modulus: 7.30 x 10^{9} dynes/mm^{2}

Poisson's Ratio: 0.252

Coefficient of Thermal Expansion (-30° to +70°C): 7.6 x 10^{-6}/°C

Coefficient of Thermal Expansion (20° to 3000°C): 8.6 x 10^{-6}/°C

Stress Birefringence, (Yellow Light): 10 nm/cm

Melt-to-Melt Mean Index Tolerance: ±0.001

Homogeneity within Melt: ±1 x 10^{-4}

Striae Grade (MIL-G-174-A): A

Transformation Temperature: 592°C

Climate Resistance: 2

Stain Resistance: 1

Acid Resistance: 3.3

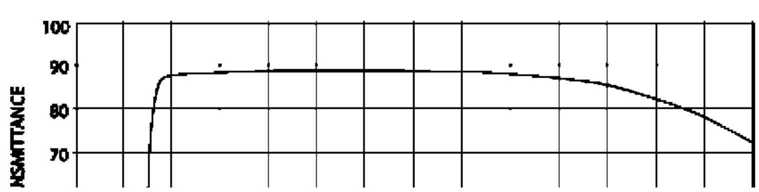
Alkali Resistance: 1.2

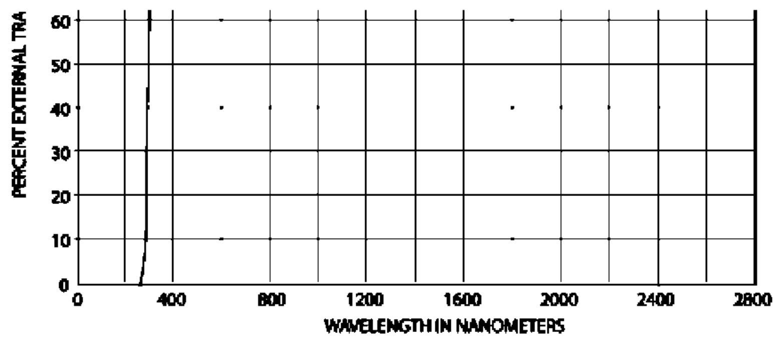
Phosphate Resistance: 2.0

Knoop Hardness: 530

Dispersion Constants:

B_1 = 1.12365662
B_2 = 3.09276848x10^{-1}
B_3 = 8.81511957x10^{-1}
C_1 = 6.44742752x10^{-3}
C_2 = 2.22284402x10^{-2}
C_3 = 1.07297751x10^{2}





External transmission for 10-mm-thick LaSFN9 glass

Physical Constants of BAK1 Glass

Wavelength (nm)	Refractive Index *n*	Fraunhofer Designation	Source	Spectral Region
351.1	1.60062	--	Ar laser	UV
363.8	1.59744	--	Ar laser	UV
404.7	1.58941	h	Hg arc	Violet
435.8	1.58488	g	Hg arc	Blue
441.6	1.58415	--	HeCd laser	Blue
457.9	1.58226	--	Ar laser	Blue
465.8	1.58141	--	Ar laser	Blue
472.7	1.58071	--	Ar laser	Blue
476.5	1.58034	--	Ar laser	Blue
480.0	1.58000	F'	Cd arc	Blue
486.1	1.57943	F	H_2 arc	Blue
488.0	1.57927	--	Ar laser	Blue
496.5	1.57852	--	Ar laser	Green
501.7	1.57809	--	Ar laser	Green
514.5	1.57707	--	Ar laser	Green
532.0	1.57580	--	Nd laser	Green
546.1	1.57487	e	Hg arc	Green
587.6	1.57250	d	He arc	Yellow
589.3	1.57241	D	Na arc	Yellow
632.8	1.57041	--	HeNe laser	Red
643.8	1.56997	C'	Cd arc	Red
656.3	1.56949	C	H_2 arc	Red
694.3	1.56816	--	Ruby laser	Red
786.0	1.56564	--	--	IR
821.0	1.56485	--	--	IR
830.0	1.56466	--	GaAlAs laser	IR
852.1	1.56421	s	Ce arc	IR
904.0	1.56325	--	GaAS laser	IR

1014.0	1.56152	t	Hg arc	IR
1060.0	1.56088	--	Nd laser	IR
1300.0	1.55796	--	InGaAsP laser	IR
1500.0	1.55575	--	--	IR
1550.0	1.55520	--	--	IR
1970.1	1.55032	--	Hg arc	IR
2325.4	1.54556	--	Hg arc	IR

F2 Glass

Abbé Constant: 36.37

Density: 3.61 g/cm^{-3}

Young's Modulus: 5.70 x 10^{9} dynes/mm^{2}

Poisson's Ratio: 0.220

Coefficient of Thermal Expansion (-30° to +70°C): 8.2x10^{-6}/°C

Coefficient of Thermal Expansion (20° to 3000°C): 9.2 x 10^{-6}/°C

Stress Birefringence, (Yellow Light): 10 nm/cm

Melt-to-Melt Mean Index Tolerance: ±0.001

Homogeneity within Melt: ±1 x 10^{-4}

Striae Grade (MIL-G-174-A): A

Transformation Temperature: 438°C

Climate Resistance: 1

Stain Resistance: 0

Acid Resistance: 1.0

Alkali Resistance: 1.3

Phosphate Resistance: 1.3

Knoop Hardness: 420

Dispersion Constants:

B_1 = 1.34533359

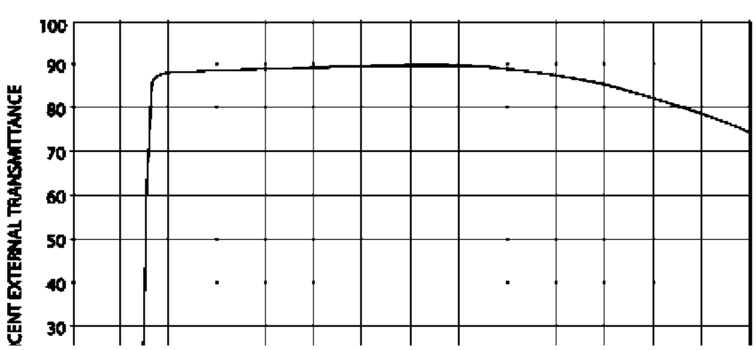
B_2 = 2.09073176x10^{-1}

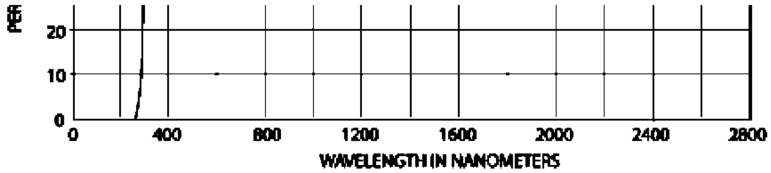
B_3 = 9.37357162x10^{-1}

C_1 = 9.97743871x10^{-3}

C_2 = 4.70450767x10^{-2}

C_3 = 1.11886764x10^{2}





External transmission for 10-mm-thick F2 glass

Physical Constants of F2 Glass

Wavelength (nm)	Refractive Index *n*	Fraunhofer Designation	Source	Spectral Region
351.1	1.67359	--	Ar laser	UV
363.8	1.66682	--	Ar laser	UV
404.7	1.65064	h	Hg arc	Violet
435.8	1.64202	g	Hg arc	Blue
441.6	1.64067	--	HeCd laser	Blue
457.9	1.63718	--	Ar laser	Blue
465.8	1.63564	--	Ar laser	Blue
472.7	1.63437	--	Ar laser	Blue
476.5	1.63370	--	Ar laser	Blue
480.0	1.63310	F'	Cd arc	Blue
486.1	1.63208	F	H_2 arc	Blue
488.0	1.63178	--	Ar laser	Blue
496.5	1.63046	--	Ar laser	Green
501.7	1.62969	--	Ar laser	Green
514.5	1.62790	--	Ar laser	Green
532.0	1.62569	--	Nd laser	Green
546.1	1.62408	e	Hg arc	Green
587.6	1.62004	d	He arc	Yellow
589.3	1.61989	D	Na arc	Yellow
632.8	1.61656	--	HeNe laser	Red
643.8	1.61582	C'	Cd arc	Red
656.3	1.61503	C	H_2 arc	Red
694.3	1.61288	--	Ruby laser	Red
786.0	1.60889	--	--	IR
821.0	1.60768	--	--	IR
830.0	1.60739	--	GaAlAs laser	IR
852.1	1.60671	s	Ce arc	IR
904.0	1.60528	--	GaAS laser	IR
1014.0	1.60279	t	Hg arc	IR
1060.0	1.60190	--	Nd laser	IR
1300.0	1.59813	--	InGaAsP laser	IR
1500.0	1.59550	--	--	IR

1550.0	1.59487	--	--	IR
1970.1	1.58958	--	Hg arc	IR
2325.4	1.58465	--	Hg arc	IR

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Material Properties

Synthetic Fused Silica

Fused silica is an ideal optical material for many applications. It is transparent over a wide spectral range, has a low coefficient of thermal expansion, and is resistant to scratching and thermal shock.

Synthetic fused silica (amorphous silicon dioxide) is formed by chemical combination of silicon and oxygen. It is not to be confused with fused quartz, which is made by crushing and melting natural crystals, or by fusing silica sand, which results in a granular microstructure and bubble entrapment. Microstructure and impurities lead to local index variations and contribute, along with bubbles and opaque particles, to reduced transmission throughout the spectrum.

Synthetic fused silica is far purer than fused quartz. This increased purity ensures higher ultraviolet transmission and freedom from striae or inclusions. The synthetic fused-silica materials used by Melles Griot are manufactured by flame hydrolysis to extremely high standards. The resultant material is colorless and non-crystalline, and it has an impurity content of only about one part per million. Controlling the purity of reactants and the conditions of reaction ensures the high quality of the synthetic fused silica from which our lenses are made.

Synthetic fused-silica lenses offer a number of advantages over glass or fused quartz:

- Greater ultraviolet and infrared transmission
- Low coefficient of thermal expansion, which provides stability and resistance to thermal shock over large temperature excursions
- Wider thermal operating range
- Increased hardness and resistance to scratching
- Much higher resistance to radiation darkening from ultraviolet, X-rays, gamma rays, and neutrons.

Optical-quality synthetic fused silica (OQSFS) lenses are ideally suited for applications in energy-gathering and imaging systems in the mid-ultraviolet, visible, and near-infrared spectral regions. The low dispersion of fused silica reduces chromatic aberration.

UV-grade synthetic fused silica (UVGSFS) is selected to offer the highest transmission (especially in the deep ultraviolet) and very low fluorescence levels (approximately 0.1% that of fused natural quartz excited at 254 nm). UV-grade synthetic fused silica does not fluoresce in response to wavelengths longer than 290 nm. In deep ultraviolet applications, UV-grade synthetic fused silica is an ideal choice. Its tight index tolerance ensures highly predictable lens specifications.

The table below shows the refractive index of a typical UV-grade synthetic fused silica versus wavelength at 20ºC. To obtain the index for optical-quality synthetic fused silica, round the values off to the fourth decimal place.

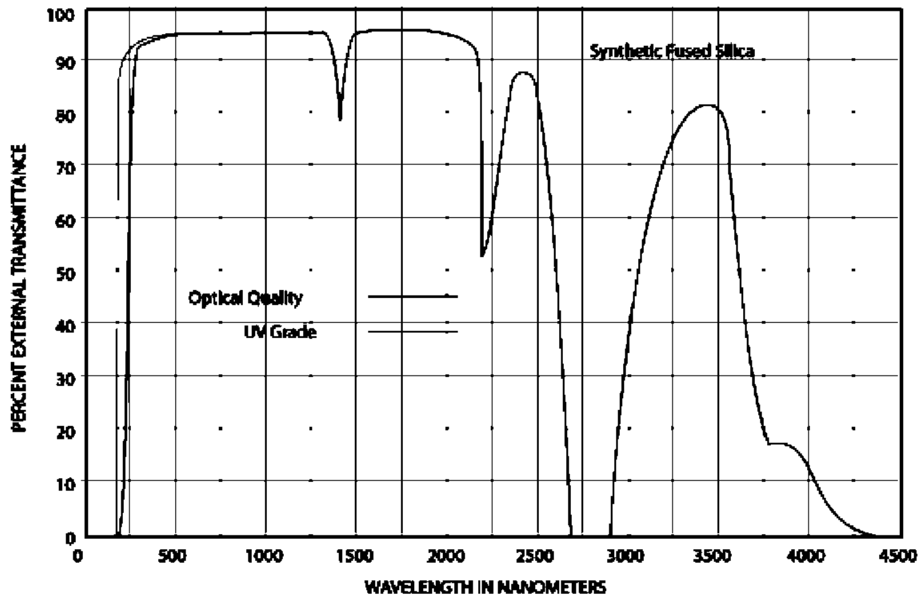
Refractive Index of UV-Grade Synthetic Fused Silica (accuracy ±3 x 10^{-5})

Wavelength (nm)	Index of Refraction	Wavelength (nm)	Index of Refraction
180.0	1.58529	532.0	1.46071
190.0	1.56572	546.1	1.46008
200.0	1.55051	587.6	1.45846
213.9	1.53431	589.3	1.45840
226.7	1.52275	632.8	1.45702
230.2	1.52008	643.8	1.45670
239.9	1.51337	656.3	1.45637
248.3	1.50840	694.3	1.45542
265.2	1.50003	706.5	1.45515
275.3	1.49591	786.0	1.45356
280.3	1.49404	820.0	1.45298
289.4	1.49099	830.0	1.45282
296.7	1.48873	852.1	1.45247
302.2	1.48719	904.0	1.45170
330.3	1.48054	1014.0	1.45024
340.4	1.47858	1064.0	1.44963
351.1	1.47671	1100.0	1.44920
361.1	1.47513	1200.0	1.44805
365.0	1.47454	1300.0	1.44692
404.7	1.46962	1400.0	1.44578
435.8	1.46669	1500.0	1.44462
441.6	1.46622	1550.0	1.44402
457.9	1.46498	1660.0	1.44267
476.5	1.46372	1700.0	1.44217
486.1	1.46313	1800.0	1.44087
488.0	1.46301	1900.0	1.43951
496.5	1.46252	2000.0	1.43809
514.5	1.46156	2100.0	1.43659

Glass transmittances are affected by thermal history after manufacture, as well as during the manufacturing process. Depending on the manufacturer and subsequent thermal processing (coating, annealing, or tempering), it is possible for any optical glass, including BK7, to show internal transmittance reductions of several percent across the entire spectrum with external transmittance correspondingly affected. Transmittance of all glass is especially uncertain at wavelengths approaching the water absorption band at 2.7 µm.

Synthetic fused silica also shows batch-to-batch transmittance variations, especially in deep ultraviolet and infrared. These variations are related to manufacture and impurity content rather than subsequent history. In the ultraviolet, these variations have been attributed to uncontrollable fluctuations in metallic impurity content at the parts per billion level. Ultraviolet transmittance is the basis for the classifications UV grade and optical quality. A specification of UV grade ensures that a

specimen is represented by the broadest curve. Transmittance curves for optical quality may fall anywhere between the UVGSFS curve and the OQSFS curves shown below.

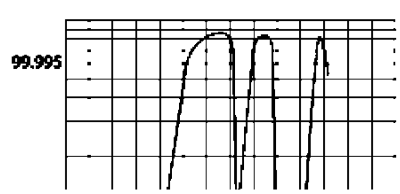


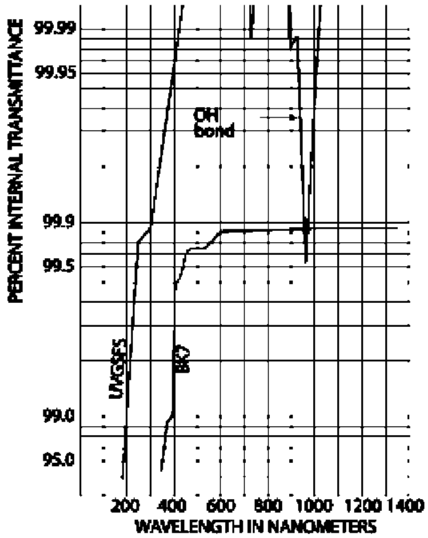
External transmittances for UV-grade and optical grade fused silica

Infrared batch-to-batch transmittance variations in synthetic fused silica are attributable to fluctuations in the OH chemical bond content. These variations are most pronounced at wavelengths near and beyond the water absorption band at 2.7 µm and are normally uncontrolled because ultraviolet transmittance is generally regarded as more important. High infrared transmittance can be ensured by appropriate manufacturing controls, but only at the sacrifice of ultraviolet transmittance.

Visible spectrum, batch-to-batch transmittance variations in synthetic fused silica are insignificant. The high ultraviolet internal transmittance of UV-grade synthetic fused silica is correlated with a visible internal transmittance that is so high it is beyond traditional methods of measurement. It is necessary to measure optical signal attenuation in fibers drawn of the material.

When comparing the internal transmittances of UV-grade synthetic fused silica and BK7 glass,shown in the figure below, it is evident that UV-grade synthetic fused silica averages about two orders of magnitude less absorption loss than BK7 across the visible spectrum (see curve). In a sample thickness of 10 mm, the internal transmittance of UV-grade synthetic fused silica differs from unity only in the fifth decimal place. The high internal transmittance of such a material can be exploited by maintaining the optic at Brewster's angle for the appropriate linear polarization, or with the assistance of high-efficiency antireflection coatings such as HEBBAR™ or one of the laser line V-coats. With these coatings it is possible to achieve external transmittances of 98.5% and 99.5%, respectively. Synthetic fused silica and HEBBAR are especially well suited to each other in visible spectrum applications.





Semilogarithmic comparison of internal transmittances of UV-grade fused silica and BK7 glass

The internal transmittance of UV-grade synthetic fused silica shows a pronounced dip at 950 nm, while the data for BK7 give no hint of a corresponding feature. It should be understood that BK7 and UVGSFS are manufactured by very different processes. One of the many differences in these materials is that UVGSFS has a much higher content of OH chemical bonds (hydroxyl content) than does BK7. The dip in UVGSFS transmittance corresponds to the OH bond resonance.

Synthetic Fused Silica Constants

Abbé Constant: 67.8 ± 0.5
Change of Refractive Index with Temperature (0° to 700°C: 1.28×10^{-5}/°C
Homogeneity (maximum index variation over 10-cm aperture) : 2×10^{-5}
Density (at 25°C): 2.20 g cm^{-3}
Continuous Operating Temperature: Maximum 900°C
Coefficient of Thermal Expansion: 5.5×10^{-7}°C
Specific Heat (25°C): 0.177 cal/g°C
Dispersion Constants**

$B_1 = 0.6961663$
$B_2 = 0.4079426$
$B_3 = 0.8974794$
$C_1 = 0.0046791$
$C_2 = 0.0135121$
$C_3 = 97.9340025$

** Source: Malitson, I.H. "Interspecimen Comparison of the Refractive Index of Fused Silica," *Journal of the Optical Society of America* 55, no. 10 (October 1965): 1205-1209

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X. RELATED PROCEEDINGS APPENDIX

NONE